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PATENT APPLICATION

Flat Panel Display Unit and Method of Repairing Defects in Its Line Pattern

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A flat panel display unit and method of repairing defects in its line pattern

BACKGROUND OF THE INVENTION

The present invention relates to a flat panel display unit such as a liquid crystal display panel, and to a method for repairing line patterns formed in the flat panel display unit.

Liquid crystal display (LCD) panels are used in personal computers and other types of office automation equipment, as well as televisions and other AV equipment. An LCD panel has pixel electrodes for driving the liquid crystals with an electric field, thin film transistors (TFT), whose number corresponds to the pixel count, for applying a voltage independently to each pixel electrode, a TFT panel on which orthogonal scan lines and signal lines are formed on a glass panel for controlling TFT switching, and a back panel comprising a color filter and back plane electrode opposing the TFT panel with a specific gap therebetween in which the liquid crystals are filled.

As flat panel displays have gotten larger and display resolution has improved, the pixels have gotten smaller. This makes it increasingly difficult to manufacture defect-free products, and there is a need to

increase manufacturing yield. A common conventional way of improving yield has been to repair panels determined to be defective.

Japanese Patent Laid-open Publication (*kokai*) H4-72552 describes a method for repairing line defects in a TFT panel manufacturing process where the circuit pattern is formed with the scan lines bifurcating where the scan lines and signal lines intersect. When it is detected that there is a short at a scan line to signal line intersection during inspection prior to injecting the liquid crystals, a voltage is applied to each scan line and signal line and current flows to any short between the scan line and signal line. The defect can then be located by looking for the heat produced by current at the short by infrared inspection. The short is then electrically isolated by cutting that scan line with a YAG laser, for example, before and after the intersection with the signal line, leaving the other of the bifurcated scan lines uncut.

Japanese Patent Laid-open Publication (*kokai*) 184842/1996 describes a method of repairing an break in the wiring by coating the break with an organic solution dispensed with a glass pipette, then exposing the coated area to a laser to thermally break down the organic

complex solution, deposit a metallic film, and thus form an electrical connection across the break.

With the conventional method of repairing shorting defects the scan lines of the TFT panel bifurcate where the scan lines and signal lines cross with an interlayer insulation film therebetween so that shorting defects can be repaired, and a short on either one of the legs can be repaired. The intersecting scan line is cut with a YAG laser, for example, before and after the short at the intersection between a signal line and one of the two scan line legs, thereby electrically separating the shorting defect from the TFT circuit. Wiring material melted by the laser can, however, pass through the insulation film where the line is cut and scatter around the cut area. The protective insulation film can thus be lost around the cut, electrically exposing the scan line to the liquid crystal. As a result, in addition to there being insufficient insulation protection around the repair site, leakage current can flow from the cut part depending on the type of liquid crystal. The liquid crystals vary with the type of product, and depending upon the type of liquid crystal used this leakage current can cause point defects in the liquid crystals, orientation defects, and other problems.

Apart from shorting defects, foreign objects adhering to the panel during the process forming the lines on the TFT panel can prevent normal formation of the insulation film that is then formed to protect the lines. This results in insulation film defects that can then result in leakage current flowing from the insulation film defect to the liquid crystal. Depending upon the type of liquid crystal, this leakage current can again cause point defects in the liquid crystals, orientation defects, and other problems.

SUMMARY OF THE INVENTION

To solve the problems described above, the present invention provides a flat panel display unit with repaired interline shorting defects or line insulation defects occurring from foreign matter adhering to a line repaired, and further provides a flat panel display unit manufacturing method and apparatus for repairing interline shorting defects or line insulation defects occurring from foreign matter adhering to a line.

More specifically, a method for repairing line defects according to the present invention detects that there is a shorting defect between a scan line and signal line and identifies the location of the defect in a flat panel display unit wherein the scan lines or signal lines

or both scan lines and signal lines branch in two parts at the intersection between scan lines and signal lines disposed with an interlayer insulation film between the two parts. After locating the defect, the intersection between the scan line and signal line where the shorting defect is located is cut with a laser beam. An insulation film is then locally formed at the cut to complete the line defect repair.

The method for repairing line defects according to the present invention detects shorting defects between a scan line and signal line in a flat panel display unit having scan lines and signal lines formed with an interlayer insulation film therebetween, stores the location of the detected shorting defect, cuts the scan line by emitting a laser to the scan line near the location of the stored shorting defect, supplies an insulation material locally to the area containing the location of the cut scan line, and then cures the supplied insulation material.

These and other objects, features, and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a section view of a glass pipette and TFT panel illustrating the repair method of a first preferred embodiment of the present invention;

Fig. 2 is a plan view of a TFT panel showing the area where insulation material is coated in a first preferred embodiment of the present invention;

Fig. 3 is a section view of a glass pipette and TFT panel illustrating the repair method of a second preferred embodiment of the present invention;

Fig. 4 is a plan view of a TFT panel showing the area where insulation material is coated in a second preferred embodiment of the present invention;

Fig. 5 is a plan view and partial section view of a TFT panel showing adhesion of foreign matter leading to a defect in a third preferred embodiment of the present invention;

Fig. 6 is a plan view and partial section view of a TFT panel showing a repair method according to a third preferred embodiment of the present invention;

Fig. 7 is a section view of a glass pipette and TFT panel illustrating the repair method of a fourth preferred embodiment of the present invention;

Fig. 8 is a simplified plan view of a typical TFT panel configuration;

Fig. 9 is a section view of a TFT panel illustrating a method of repairing scan line and signal line shorting defects according to the prior art; and

Fig. 10 is a section view of a TFT panel illustrating a method of repairing scan line and signal line shorting defects according to the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention are described below with reference to the accompanying figures.

<u>Embodiment 1</u>

A first preferred embodiment of the present invention is described next below with reference to Figs. 1, 2, 8, 9, and 10. Fig. 8 is a simplified plan view of a typical TFT panel configuration. As shown in Fig. 8, a typical TFT panel has pixel electrodes 4, 4' on a glass panel 1 for changing the orientation of the liquid crystals by applying an electric field, and a TFT structure 6 formed for each pixel electrode 4 for applying a voltage to the corresponding pixel electrode 4. Plural scan lines 2 and signal lines 3 for driving each TFT according to an image signal are orthogonally disposed with an interlayer insulation film therebetween. In a VGA (Video Graphics Array) panel, for example, there

are 1920 scan lines 2; there are 2400 in an SVGA (Super Video Graphics Array) panel; and there are more than 3000 in an XGA (Extended Graphics Array) panel. A protective insulation film is also formed covering the scan lines 2 and signal lines 3. Finally, an orientation film for aligning the orientation of the liquid crystals is formed, and a second panel forming a color filter, for example, is disposed opposite the TFT panel with the liquid crystals therebetween.

This first embodiment of the invention repairs a shorting defect 7 discovered in the inspection process that looks for shorting defects in the scan lines and signal lines after the lines on the TFT panel and the protective insulation film are formed. As described in the above-cited JP 72552/1992, the location of the scan line-to-signal line short is found by applying a voltage between each scan line and signal line. Compared with normal lines, excess current flows between the scan line and signal line where there is a short, and this excess current produces heat from resistance where the lines short. The location of the short can then be identified by detecting the infrared light produced by this heat with an infrared detector. The location of the defect is then stored for use when repairing defects.

Fig. 9 is a section view at line A-A' through the shorting defect 7 shown in Fig. 8. The signal line 3 and scan line 2 are electrically isolated by an interlayer insulation film (protective insulation film) 8 at the intersection between normal scan lines and signal lines. At a shorting defect 7 caused by foreign matter, for example, the insulation between the layers is deficient and the signal line 3 and scan line 2 short at the crossover. With a circuit pattern allowing for repairing such shorts according to the prior art, the scan line bifurcates at this intersection and thus intersects with the signal line at two points.

Repairing the shorting defect is not possible when both of these intersections short at the same time. However, when there is a short at only one of the intersections, the scan line is cut with a laser 9 before and after the intersection at laser cuts 11 and 11' as shown in Fig. 9 (a). The shorting defect 7 is thus repaired by electrically separating the shorting defect 7 from the scan line 2. With this method, however, the laser 9 also removes part of the protective insulation film 8 above the laser cuts 11 and 11', thereby electrically exposing part of the scan line 2 to the liquid crystal, as shown in Fig. 9 (b).

As also shown in Fig. 10, the laser 9 melts and removes metal 10 from the scan line 2. This metal 10 scatters and typically lands in a 100 μm to 200μm diameter area around the laser cuts 11 and 11'.

The short is apparently electrically repaired and the defect resolved at this point. However, when the LCD panel is confirmed as a defect-free unit and power is supplied to the panel, an electric field leaks from the scan line 2 into the liquid crystals. Depending upon the type of liquid crystal used, this leakage current causes a crystal orientation defect apparent as a point defect.

The present invention solves this problem as described next with reference to Fig. 1. That is, after cutting the scan line 2 at laser cuts 11 and 11' by means of laser 9, an insulation film material is locally applied to a 100 μm to 200 μm diameter area around the laser cuts 11 and 11' in order to protect the laser cuts 11 and 11' and cover the scattered metal 10.

This insulation material can be locally applied by dispensing the insulation film material 13 from a glass pipette 12 having a tip diameter of several microns as taught in JP 184842/1996 using capillary action. The glass pipette 12 filled with insulation film material 13 is mounted to the arm of a manipulator (not shown in the

figure) that can be controlled and positioned to the TFT panel with micron order precision.

A gas tube is connected to the other end of the glass pipette 12. The gas tube is connected to a gas supply system (not shown in the figure) for supplying air or inert gas by means of a solenoid that operates with pulses variable from 1 ms to plural seconds.

Using a horizontally movable stage (again, not shown in the figures) on which the TFT panel is mounted and the above-noted manipulator, which can move the glass pipette 12 both horizontally and perpendicularly to the TFT panel, the glass pipette 12 is moved in the area 100 □m to 200 □m around the shorting defect based on the above short location information to contact the TFT panel surface at the shorting defect 7 while the area to be coated is viewed through an optical microscope.

Air or inert gas is then flowed into the glass pipette 12 by the gas supply system for 1 ms to plural seconds at several tens of kilopascals to spray the insulation material while controlling the coating area to locally coat the insulation film material 13 on a 100 □m to 200 □m diameter area.

The applied insulation film material 13 is, for example, a SiOx resin, polyimide resin, epoxy resin, or acrylic resin material. The specific curing method will

depend upon the characteristics of the insulation film material 13. A polyimide resin material, for example, can typically be cured by a chemical reaction induced by heating the TFT panel or coated area for a specific time to form the insulation film. The TFT panel can be heated by holding the panel in an oven held at a constant temperature for a specific time, or heat can be applied locally to the coated area using a heat lamp. This assures that the repaired site is also electrically isolated from the liquid crystals even after the LCD panel is completed, thereby enabling a shorting defect 7 to be repaired without producing point defects or other orientation defects.

Embodiment 2

When a shorting defect is repaired as described in the first embodiment above, the area on the TFT panel to which the molten scan line metal 10 scatters when the scan line is removed before and after the shorted intersection by a laser 9 depends upon the characteristics of the laser 9, but is typically a 100 μm to 200 μm in diameter. As shown in Fig. 1 this 100 μm to 200 μm diameter area is then coated with an insulation film material 13 using a glass pipette 12, and the insulation film material 13 is heat cured, for example,

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to form an insulation film over the repair site. The thickness of this locally formed insulation film is 0.3μm to 1μm, producing a thicker film portion relative to the unrepaired surrounding at the repair site.

The problem with this is that an orientation film is formed over the entire TFT panel before injecting the liquid crystals, and this orientation film is designed to align the liquid crystals in the same direction. The thicker film portion formed at the repair site, however, interferes with the desired liquid crystal orientation. In a high resolution TFT panel the pixel electrodes and also the gaps between electrodes are short, and disruption of the liquid crystals in a repair site extending in a 100 μm to 200 μm diameter area can extend to plural pixel electrodes outside the immediate repair site. In a worst case scenario the repair site is visible to the unaided eye, and will be determined defective upon inspection.

The repair method of the second embodiment of this invention solves this problem by suppressing such defects in high resolution TFT panels and other products having a short pixel electrode gap, as well as repairing defects that do occur. This second embodiment of the invention is described next with reference to Fig. 3 and Fig. 4.

Referring to Fig. 3 (a), using a horizontally movable stage (not shown in the figures) on which the TFT panel is mounted and the above-noted manipulator, which can move the glass pipette 12 both horizontally and perpendicularly to the TFT panel, the glass pipette 12 is moved in the area 100 μm to 200 μm around the shorting defect based on the above short location information and the pipette is put in contact with the TFT panel surface at the shorting defect 7 while viewing the area to be coated through an optical microscope.

Air or inert gas is then flowed into the glass pipette 12 by the gas supply system for 1 ms to plural seconds at several tens of kilopascals to spray the insulation material while controlling the coating area to locally coat the insulation film material 13. The coating area 15 can be freely determined to be an area that will not produce defects caused by the repair, this area calculated based on the pixel electrode gap of the specific TFT panel.

After coating, the glass pipette 12 is retracted by the manipulator to a site where it will not contact the laser 9. One side of the scan line 2, which bifurcates at the intersection of the shorting defect 7, is then cut at laser cuts 11 and 11' by the laser 9 as shown in Fig. 3 (b). In this case, however, the molten metal from the

scan line 2 produced by the laser 9 is trapped inside the insulation film material 13, which has not been heat cured and thus remains a high viscosity fluid. The molten metal thus remains in the insulation film material 13 and does not scatter outside the area of the coated insulation film material 13.

By thus limiting the area of scattered metal to within the coating area 15 of the insulation film material 13, repairs can be made in an area in which orientation defects caused by the repair will not occur. As shown in Fig. 3 (c), however, because the thickness of the insulation film material 13 is thinner where the line is cut by the laser 9, insulation material 13 is reapplied by the glass pipette 12 in coating area 16 to increase the thickness of the insulation material 13 as shown in Fig. 3 (d). It should be noted that this coating area 16 is inside the boundaries of the first coating area 15.

The insulation film material 13 is then cured with a curing method determined by the characteristics of the insulation film material 13 to form an insulation film.

As a result, the repair site is also electrically isolated from the liquid crystals in the completed LCD panel unit. A shorting defect 7 can therefore be repaired without the repair creating a point defect or other

orientation defect even in high resolution TFT panels where the pixel electrodes and pixel electrode gap are short.

It will also be apparent that because the area in which the molten scan line 2 metal scatters is suppressed by this second embodiment of the invention, the area to which the insulation film material 13 is coated can be restricted to the scan line 2 and adjacent area, and repair is possible without affecting the surrounding pixel electrodes.

Embodiment 3

A third preferred embodiment of the present invention is described next with reference to Fig. 5 and Fig. 6. Fig. 5 shows a TFT panel after the protective insulation film is formed. In this case, however, foreign matter 17 adheres to the scan line 2 during the line formation process, and as shown in the B-B' section view through the foreign matter 17, the foreign matter 17 on the scan line 2 obtrudes through the protective insulation film 8. When this happens, an electric field from the scan line 2 will leak into the liquid crystals from around the foreign matter 17 when current is supplied to the finished LCD panel whether the foreign matter 17 is a dielectric or conductor, possibly

resulting in point defects or other orientation defects depending upon the type of liquid crystal.

To prevent such defects it is first necessary to inspect for foreign matter in the TFT panel inspection process following insulation film formation, and identify the location of any foreign matter 17 that could lead to such orientation defects. The defect is then repaired using the process described in either the above first or second embodiment.

This is described next with reference to Fig. 6. As in the first or second embodiment, using a horizontally movable stage (not shown in the figures) on which the TFT panel is mounted and the above-noted manipulator, which can move the glass pipette 12 both horizontally and perpendicularly to the TFT panel, the glass pipette 12 is moved near the foreign matter 17 (within 100 μm to 200 μm) to be repaired on the TFT panel based on the location of the foreign matter identified in the inspection process and finally the glass pipette 12 is brought in contact with the TFT panel surface at the foreign matter 17 while viewing the area to be coated through an optical microscope.

Air or inert gas is then flowed into the glass pipette 12 by the gas supply system for 1 ms to plural seconds at several ten kilopascals to spray the

insulation material while controlling the coating area to coat the foreign matter 17 with the insulation material 18 in the glass pipette 12. As shown in the section view through line C-C' in Fig. 6, the foreign matter 17 is completely covered with the insulation material 18.

The insulation material 18 can be any of the insulation materials described in the first and second embodiment, and is then cured by heat curing or other process determined by the characteristics of the insulation material 18 to form the insulation film. The repair site is thus insulated from the liquid crystals in the completed LCD panel, and point defects or other orientation defects caused by foreign matter 17 can be suppressed.

<u>Embodiment 4</u>

A fourth embodiment of the present invention is described next with reference to Fig. 7. The third embodiment above describes a method of suppressing point defects resulting from foreign matter, but the described method can only be used when the distance d from the TFT panel surface to the top of the foreign object is less than or equal to the distance D between TFT panel surface and the opposing color filter panel so that there is no

contact with the opposing color filter panel on the other side of the liquid crystals.

When d > D and there is the danger that foreign object 19 will contact the opposing panel as shown in Fig. 7 (a), the laser 9 is positioned and emitted to the area containing the foreign object 19 using a horizontally movable stage (not shown in the figure) on which the TFT panel is mounted based on the detected location of the foreign object 19 in order to remove the foreign object 19 and adjacent scan line 2 and protective insulation film 8. It should be noted that the size and shape of the foreign object 19 are variable, the cross section of the laser 9 cannot be shaped to a spot of any desired shape. The laser 9 cross section must therefore be a spot larger than the foreign object 19. This assures that the scan line 2 and protective insulation film 8 around the foreign object 19 will be simultaneously removed.

As shown in Fig. 7 (c), this process removes the foreign object 19 and assures there will be no contact with the other panel. As described in the above first to third embodiments, the glass pipette 12 is moved using a horizontally movable stage (not shown in the figures) on which the TFT panel is mounted and the above-noted manipulator, which can move the glass pipette 12 both

horizontally and perpendicularly to the TFT panel. Based on the detected location information, the glass pipette 12 is thus positioned to the area (within 100 □m to 200 □m) of the repair site of the TFT panel where the foreign object 19 was removed by the laser, and finally brought in contact with the TFT panel surface where the foreign object 19 was removed while viewing the area to be coated through an optical microscope.

Air or inert gas is then flowed into the glass pipette 12 by the gas supply system for 1 ms to plural seconds at several ten kilopascals to spray the insulation material while controlling the coating area to coat the repair site with the insulation material 18 in the glass pipette 12. The scan line 2 exposed portions in the processed area are completely covered by the applied insulation material 18. Furthermore, as in the first to third embodiments, the applied insulation material 18 is cured by a heat process or other process appropriate to the characteristics of the insulation material 18 to form an insulation film.

As a result of this process even large foreign objects that would contact the opposite panel can be removed and repaired. The repair site is therefore insulated from the liquid crystals even in the completed

TFT panel, and point defects resulting from such a foreign object 19 can be prevented.

It will thus be obvious to one with ordinary skill in the art that shorting defects between a scan line and signal line occurring in the manufacture of a flat display panel unit can be reliably repaired. As a result, production yield of flat panel display units can be improved.

It is also possible to prevent point defects and other orientation defects caused by foreign matter. As a result, production yield of flat panel display units can be improved.

Although the present invention has been described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will be apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims, unless they depart therefrom.